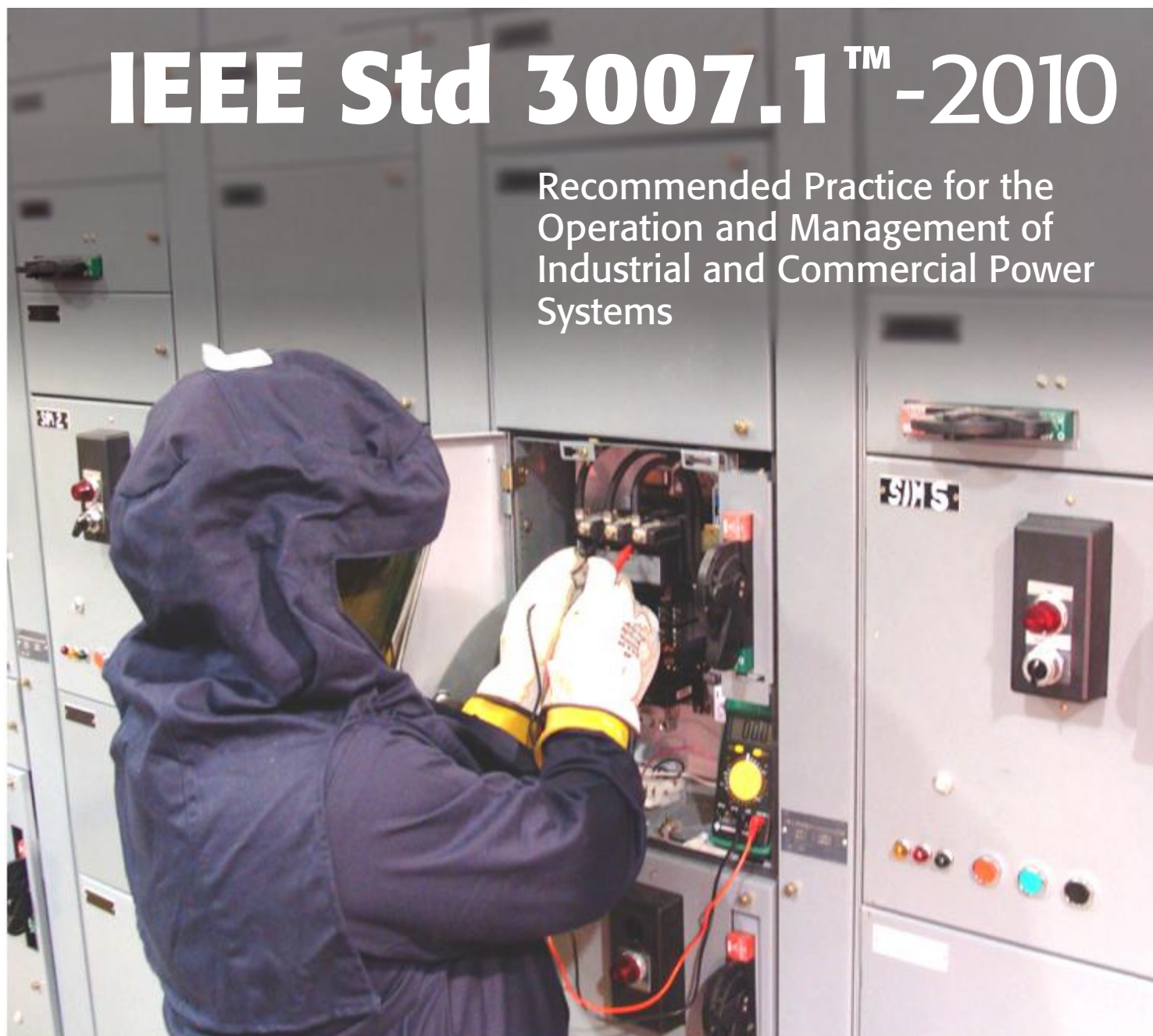


IEEE Std 3007.1™-2010

Recommended Practice for the
Operation and Management of
Industrial and Commercial Power
Systems



IEEE Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems

Sponsor

**Technical Books Coordinating Committee
of the
IEEE Industry Applications Society**

Approved 8 December 2010

IEEE-SA Standards Board

Abstract: Recommended practices for the numerous personnel who are responsible for safely operating and managing industrial and commercial electric power facilities are provided. In this recommended practice, plant engineers are provided with a reference source for the fundamentals of safe and reliable operation and management of industrial and commercial electric power distribution systems.

Keywords: clearing procedures, coordination, documentation, electrical hazards, electrical maintenance, electrical safety program, grounding, inspection, maintenance, management, operating diagrams, operation, protective devices, record keeping, safety, single-line diagram, system control, testing

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Introduction

This introduction is not part of IEEE Std 3007.1-2010, IEEE Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems.

This recommended practice was developed by the Technical Books Coordinating Committee of the Industrial and Commercial Power Systems Department of the IEEE Industry Applications Society, as part of a project to repackage the popular series of “IEEE Color Books.” The goal of this project is to speed up the revision process, eliminate duplicate material, and facilitate the use of modern publishing and distribution technologies.

When this project is completed, the technical material included in the 13 “Color Books” will be included in a series of new standards—the most significant of which will be a new book, IEEE Std 3000, IEEE Recommended Practice for the Engineering of Industrial and Commercial Power Systems. The new book will cover the fundamentals of planning, design, analysis, construction, installation, start-up, operation, and maintenance of electrical systems in industrial and commercial facilities. Approximately 60 additional “dot” standards, organized into the following categories, will provide in-depth treatment of many of the topics to be introduced by IEEE Std 3000:

- Power Systems Design (3001 series)
- Power Systems Analysis (3002 series)
- Power Systems Grounding (3003 series)
- Protection and Coordination (3004 series)
- Emergency, Stand-By Power, and Energy Management Systems (3005 series)
- Power Systems Reliability (3006 series)
- Power Systems Maintenance, Operations, and Safety (3007 series)

In many cases, the material in a “dot” standard comes from a particular chapter of a particular color book. In other cases, material from several color books has been combined into a new “dot” standard.

The purpose of this document is to provide guidance for the numerous personnel who are responsible for operating and managing industrial and commercial electric power facilities.

This recommended practice evolved from and built on the most recent revisions to the “operations” chapters (Chapter 2 through Chapter 4) of the 1998 edition of IEEE Std 902™, IEEE Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems (also known as the *IEEE Yellow Book*).^a Prior to the Color Books reorganization process, the Yellow Book Working Group had completed a draft revision (March 2007) that was approaching readiness for publishing. Unfortunately, it was not completed prior to the reorganization process.

The original working groups for IEEE Std 902 were sponsored by the Industrial and Commercial Power Systems Engineering Committee of the IEEE Industry Applications Society through the Safety, Operations, and Maintenance Subcommittee. Work related to this document, IEEE Std 3007.1, is now reported to the Technical Books Coordinating Committee through the Power Systems Maintenance, Operations, and Safety Editorial Working Group.

Information on references can be found in Clause 2.

When the original IEEE Std 902 was contemplated and created, the requirements of the Occupational Safety and Health Act (OSHA, a U.S. law) and the limited information that were generally offered at the time were prime driving forces. Although some things have changed since then, the basic drivers and philosophies for maintenance, safety, and operation have remained relatively unchanged. The intent of this document is to provide up-to-date basic philosophies and approaches to problems without going into great detail on any one aspect of the subject. Where readers require more depth of information, references have been provided for further study.

The Working Group recognizes the international applicability of this guide. The Working Group also recognizes that this standard refers to some practices that are U.S. oriented. As a practical matter, the consensus was to publish this edition with the intent that international standards would supplement this guide as appropriate. The Working Group is committed to making this an international standard as far as input is provided for this recommended practice, as well as future editions.

Over the years, a great many people have contributed to the development of this recommended practice. The most recent working group participants are listed in the participants section of the front matter. To all others who may have contributed in some way or were former working group members that helped develop or work on IEEE Std 902, we would like to extend our gratitude and appreciation for your efforts.

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Participants

At the time this recommended practice was submitted to the IEEE-SA Standards Board for approval, the Maintenance, Operations and Safety (MOS) Working Group of the Technical Books Coordinating Committee of the Industrial and Commercial Power Systems Department of the Industry Applications Society had the following membership:

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IEEE Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems

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1. Overview

1.1 Scope

This recommended practice covers the operation and management of industrial and commercial power systems. It covers the fundamental elements of system operation including, but not limited to, proper documentation, system management, control responsibilities, and clearing procedures.

1.2 General

Even with the best design and equipment, the expected safe and reliable performance of a power system is largely dependent upon the quality and capability of its operation and management. Optimizing system operation through proper management can often be one of the most cost-effective approaches in improving system performance.

The phrase “industrial and commercial power systems” covers a broad spectrum. At one end of this spectrum is the large industrial complex that can justify a staff of highly skilled and knowledgeable maintenance and operation personnel. At the other end of this spectrum is the small simple system in which the owner may have little or no electrical expertise.

The objective of this guide is to provide plant engineers with a reference source for the fundamentals of safe and reliable operation and management of industrial and commercial electric power distribution systems. These basic fundamentals are independent of system size or complexity. The most effective use of the information contained in this recommended practice would be its inclusion in long-term operation and management plans tailored to the individual needs of each power system.

A good long-term operation and management strategy for any power distribution system also includes good maintenance practices, creation of a safe working environment, and establishment of good safe work practices. Although maintenance and safety practices are beyond the scope of this document, it is recommended that this document's two companion documents, IEEE P3007.2™, Draft Recommended Practice for the Maintenance of Industrial and Commercial Power Systems, and IEEE P3007.3™, Draft Recommended Practice for Safety in Industrial and Commercial Power Systems, be used closely and in conjunction with this document.¹

The fundamental elements of safe and reliable operation and management of power distribution systems include:

- a) Maintenance and operation considerations in system design including documentation of the power system's design basis (requirements, restrictions, limitations)
- b) Safety considerations in system design ("Safety by Design") and system management (safety by management procedures)
- c) Development of maintenance and operations plans to sustain long-term reliability and safety
- d) Development of record keeping and documentation files
- e) Development and implementation of testing and inspection methods
- f) Development of procedures for auditing maintenance and operation performance
- g) Development of procedures to enhance personnel safety

Although maintenance and safety are outside of the scope of this recommended practice, they fundamentally play a significant role in proper power system operation and management and, as stated earlier, are addressed in this standard's companion documents. However, proper operation and management also includes properly addressing record keeping and documentation, power system operation and management, and system control responsibilities and clearing (also known by several other names including isolation, guarantee of isolation, or clearance) procedures. These last areas are the emphasis of this recommended practice.

1.3 How to use this recommended practice

Clause 1 provides an overview of this recommended practice.

Clause 2 includes the normative references for this recommended practice.

Clause 3 includes definitions, acronyms, and abbreviations used within this recommended practice.

Clause 4 covers the importance of proper power system documentation, including system-operating diagrams, for the proper operation and management of any power distribution system.

Clause 5 discusses proper system operation and management including the importance of proper administrative procedures, load distribution, protection of the power system's integrity, power factor correction, protective device coordination, and operating economics.

¹ Information on references can be found in Clause 2.

Clause 6 discusses power system control responsibilities and switching and clearing procedures.

For further information, Annex A provides an informative bibliography.

The overall intent of this recommended practice is to offer guidance for the establishment of practices, procedures, and organizational capabilities that support safe and reliable power distribution system operation and management. It is likely to be of greatest value to the power-oriented engineer with limited experience in this area. It can also be an aid to all engineers responsible for the operation and maintenance of industrial and commercial power systems.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE P3007.2/D1 (August 2009), Draft Recommended Practice for the Maintenance of Industrial and Commercial Power Systems.²

IEEE P3007.3/D1 (September 2010), Draft Recommended Practice for Electrical Safety of Industrial and Commercial Power Systems.

IEEE Std 902-1998, IEEE Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems (*IEEE Yellow Book*).^{3, 4}

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this recommended practice, the following terms and definitions apply. *The IEEE Standards Dictionary: Glossary of Terms & Definitions* [B5] should be consulted for terms not defined in this clause.^{5, 6}

facility engineer: Synonymous with the term plant engineer, it means the engineer in charge of all engineering aspects within the owner's facility or plant. The facility engineer may in some cases also be the plant manager.

NOTE—In the context of this document, the facility engineer is considered the facility engineer with ultimate authority over the plant's electrical power system. Typically, the term facility engineer indicates an engineer under the direct employment of the owner; however, there are instances where a separate firm may provide facility engineering and/or management services for the owner.

² Numbers preceded by P are IEEE authorized standards projects that were not approved by the IEEE-SA Standards Board at the time this publication went to press. For information about obtaining drafts, contact the IEEE.

³ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

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⁵ *The IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at <http://shop.ieee.org/>.

⁶ The numbers in brackets correspond to those of the bibliography in Annex A.

operator: The person or group responsible for operating the plant's power system. The operator may or may not be an engineer, but should have a working understanding of the electrical power system.

owner: The individual (the manager, plant manager) responsible to the ownership of a plant or facility for overall management of the plant or facility. In some cases, this could be the actual owner or the facility engineer.

owner's representative: An individual or group of individuals hired by the owner to make related decisions on behalf of the owner. These decisions could be related to plant engineering or management, but are considered decisions made directly by the owner.

plant engineer: *See: facility engineer.*

plant manager: *See: owner.*

plant operator: *See: operator.*

system operator: *See: operator.*

utility: The entity or entities that serve power to the plant at the plant's power service entrance(s).

3.2 Acronyms and abbreviations

CFR	Code of Federal Regulations
FDR	feeder
LTC	load tap changing
NFPA	National Fire Protection Agency
OSHA	Occupational Health and Safety Administration
PPE	personal protective equipment
SCADA	Supervisory Control and Data Acquisition

4. Power system documentation

4.1 General

Obtaining and maintaining proper power system documentation is one of the most important aspects of proper operation and management of industrial and commercial power systems. Therefore, before moving on to other areas related to system operation and management, a clause dedicated to a discussion of system documentation, including power system operating diagrams, is appropriate. Power system documentation includes system-operating diagrams such as single-line drawings, panel directories, equipment layouts, and site plans. Additionally, power system documentation may include vendor drawings and instruction manuals, plant drawings, maintenance histories, spare parts lists, and other documentation related to the power system. Typically, all of these are important to operating and managing the power system properly.

System-operating diagrams are the road maps to the operation and maintenance of an industrial or commercial power system. These diagrams are considered an essential tool for working on a power system. Without the guidance that is provided by the information contained on these system-operating diagrams, the operation and maintenance of an industrial or commercial complex would be extremely difficult and potentially unsafe.

Vendor's drawings and instruction manuals, plant drawings, maintenance histories, spare parts lists, standard operating procedures, and other documents should be systematically filed and readily available to the personnel who are involved in system operation and maintenance. A plant's core distribution system may have a life of 30 or more years. Therefore, complete, up-to-date equipment documentation is essential not only for supporting routine daily activity, but also for the successful implementation of system expansion or modification. System documentation should include simplified single-line drawings that show only power sources, transformers, voltage levels, major loads, disconnecting devices, switches, and circuit breakers. These drawings are essential for the planning and illustration of power system operation and activity. A master file should be kept in which all revisions are noted and the drawings are subsequently updated because there may be several copies or files of essential drawings that depict the plant. The use of computer-aided drafting systems may expedite the process.

The equipment identification on the drawings should match the labels on the actual equipment in the field. Frequently, equipment identification is incomplete and poorly located. Staff reliance on power system documentation alone may result in errors, especially if a good accurate record keeping system is not in place. Therefore, poorly placed or inaccurate labels should be relocated or replaced as soon as practical and design and/or construction documents should be corrected to "as-built" status as early in the construction process as possible to maintain accurate records. Disconnecting means, switch operators, circuit breaker control switches, circuit breakers, push buttons, motors, and other devices should have complete stand-alone identification nameplates attached in immediate full view (e.g., "FDR 12, Sub. 3" versus "FDR 12" for a switch control handle indicating that Feeder 12 feeds Substation No. 3). Identification should be unique and affixed to all associated apparatus, mirroring the identification included on the drawings. The location of the identification nameplate should be conspicuous and can be as critical as the accuracy of the nameplate.

Critical process operations have been accidentally shut down because circuit breakers in panelboards were not properly identified. The identification of circuits during commissioning should always be verified. Per OSHA 29 CFR 1910.303(f) [B4], identification of disconnecting means and circuits requires that each disconnecting means be legibly marked to indicate its purpose. A mandatory policy requiring the regular review and updating of panelboard schedules should be instituted in order to comply with the OSHA requirements. Panelboard labels should provide a full and clear listing of all loads served by each overcurrent device.

No standard diagram or type of diagram that is available can suffice for all industrial plants or commercial complexes. It is also true that no standard electric distribution system is adaptable to all industrial plants because two plants rarely have the same requirements. However, consistency at each site is one of the most important factors in keeping the diagrams readable and understandable. Subclause 4.2 outlines the types of diagrams and information that are available to map any distribution system.

4.2 Single-line diagram (one-line diagram)

4.2.1 General

A reliable single-line diagram of an industrial or commercial electrical power distribution system is an essential and invaluable tool. It may also be called a one-line diagram or operating single-line diagram (suggesting it has all the information that an operator of the system would need). The single-line diagram indicates, by single lines and standard symbols, the course and component parts of an electric circuit or

system of circuits. The symbols that are commonly used in single-line diagrams are defined in IEEE Std 315™-1975 [B9].

The single-line diagram is a road map of the distribution system that traces the flow of power into and through the system. The single-line diagram identifies the points at which power is, or can be, supplied into the system and the point(s) at which power should be disconnected in order to clear or isolate any portion of the system.

4.2.2 Characteristics of an accurate diagram

Maintaining the accuracy of single-line diagrams provides a valuable and critical resource to the system operator, maintenance personnel, and others that work on or with the power system. An inaccurate diagram should never be relied upon as this can often be worse than using no diagram at all. In fact, this is considered such an important aspect in the United States that it is specifically addressed in Chapter 2 of NFPA 70E-2009 [B14], where 205.2 requires that single-line diagrams be kept accurate.

The following characteristics should help to improve accuracy as well as ease of interpretation:

- a) *Keep it as simple as possible for the intended purpose.* A fundamental single-line diagram should be made up of short, straight lines and components, similar to the manner in which a block diagram is drawn. It should be relatively easy to get the overall picture of the whole electrical system. All, or as much as possible, of the system should be kept to one sheet. If the system is very large, and more than one sheet is necessary, then the break should be made at voltage levels or at distribution centers.
- b) *Maintain relative geographic relations.* In many cases, it is possible to superimpose a form of the single-line diagram onto the facility's plot plan. This is very helpful toward a quick understanding of the location of the power system's major components for operating purposes. It may, however, be more difficult to comprehend the overall system operation from this drawing. Such a drawing could be used for relatively simple systems. For more complex systems, a separate site drawing should be used in addition to the fundamental single-line diagram.
- c) *Maintain the approximate relative positions of components when producing the single-line diagram.* The drawing should be as simple as possible and should be laid out in the same relationship as an operator would view the equipment. The diagram does not need to show geographical relationships at the expense of simplicity.

NOTE—A site plan with equipment locations should accompany the single-line diagram.

- d) *Avoid duplication.* Each symbol, figure, and letter has a definite meaning. The reader should be able to interpret each without any confusion. In this regard, equipment names should be selected before publishing the document and these names should be used consistently. Where possible, abbreviations and acronyms should be avoided, but where necessary a legend should accompany the documents to define all abbreviations and acronyms.
- e) *Show all relevant known factors.* Depending upon the use of the single-line diagram, some or all of the following details may be important to include on the drawings:
 - Manufacturers' type designations and ratings of apparatus.
 - Ratios of current and potential transformers and taps to be used on multi-ratio transformers.
 - Connections of power transformer windings, phasor diagrams, and load tap changer (LTC) location and arrangement.
 - Circuit breaker manufacturer and model, settings and ratings in volts, amperes, and short-circuit interrupting rating.

- Switch and fuse manufacturer and model, ratings in volts, amperes, and short-circuit interrupting rating.
 - Function of relays and relay settings (although often settings are kept in a site relay database, spreadsheet, or power system software program). Device functions used should be from IEEE Std C37.2™-2008 [B12].
 - Ratings of motors, generators, and power transformers.
 - Ratings of surge arrestors, surge capacitors, transient voltage surge arrestors, and capacitor banks.
 - Number, size, type of conductors, length, method of installation (e.g., cable tray, rigid steel conduit), ampacity, and thermal ratings.
 - Voltage, phases, frequency, and phase rotation of all incoming circuits. The type of supply system (wye or delta, grounded [solidly, resistance, or reactance], or ungrounded) and the available short-circuit currents may be indicated. Note that available short circuit current is dependent upon the power system configuration of the facility as well as the power utility at a specific moment in time. Therefore, it is a “snap-shot” and, unless a detailed explanation is provided, it should generally not be included on a single-line diagram.
- f) *Future plans.* When future plans are known, they may be shown on the diagram and/or explained by notes. However, it may be better to include future plans on staged and/or ultimate diagrams to prevent confusion with what exists today.
- g) *Other considerations.* Refer to IEEE Std 141™-1993 (*The Red Book*) [B6] for further discussion of single-line diagrams.

4.2.3 Uses of the single-line diagram

The single-line diagram may be used in a number of important ways in operating and maintaining an industrial or commercial power distribution system. Frequently, the single-line diagram, with all of the listed information, becomes too crowded for information to be used effectively in some of the operating activities. In those instances, it may be better to produce a set of single-line diagrams, with each different diagram in the set containing the pertinent information that is required for a particular activity or set of activities. However, it is often difficult to maintain more than one set of single-line diagrams and care must be taken to keep them all accurate; one set of the single line diagrams should always be considered the master set. To minimize drawing updating efforts, often two or more of these special single-line diagrams can be combined in one 2-D graphics file using layering techniques. Another alternative is to keep some of the information in separate models, e.g., arc flash model software, or files rather than on another set of single-line diagrams. The diagrams could reference this additional information.

Some of the needs for special single-line diagrams include:

- a) *Switching functions.* When the primary use of the diagram is to provide information to system operators for switching in order to isolate portions for maintenance or for load control, then only the data required to make the decisions necessary for system switching are included on the diagram. Sometimes, when the distribution system is complex, a separate version of the single-line diagram in block form is more usable than a complete single-line diagram. This may be identified as a “system operating diagram.” Note that switching diagrams should identify all sources of power and routes that could feed the area or equipment to be isolated including potential sources of back-feed such as standby generators and the secondary of voltage transformers.
- b) *Power or current flow control diagrams.* These diagrams are used exclusively for power or current flow control. It only includes the data that show system component capacities and other data that pertain to power or current flow. These diagrams may, for example, include LTC transformer information because the voltage, current, and power are interrelated for any particular load.

- c) *Relaying and relay logic diagrams.* These single-line diagrams are used to describe the system protective relay systems. These diagrams are used particularly as logic and tripping diagrams that may contain a unique language used only to depict the sequence of relay or system protective component operation under various fault conditions.
- d) *Impedance diagrams.* These are single-line diagrams that show the system input impedance and the impedance of all system components in which the impedance of each circuit branch is maintained for system short-circuit analysis. Diagrams should include all reactance data on large rotating apparatus or the equivalent data for groups of machines. In instances where the impedance may be tied to the equipment's operation, show the alternative impedances for each possible operating scenario, e.g., on an LTC transformer, show the impedance at the different operating taps and identify the nominal setting.
- e) *Arc flash hazard.* The single-line diagram is the basis for calculation of arc flash hazard levels and for development of an arc flash hazard program, as described in NFPA 70E-2009 [B14], IEEE Std 1584™-2002 [B11], and 29 CFR [B4]. An arc flash hazard analysis should be conducted in conjunction with a short-circuit analysis and a protective device coordination study. All of the information required for an arc flash hazard study does not need to appear on the single-line diagram; however, the single-line diagram is a key instrument in properly conducting an accurate arc flash hazard analysis and the model used for the analysis must match the single-line diagram.

4.2.4 Special single-line diagrams

4.2.4.1 General

For a large facility that has regularly changing conditions on its electrical distribution system, a mimic bus-type, single-line diagram can be a useful tool. This type of single-line diagram could be a fairly simple pegboard arrangement with movable circuit symbols and tapes in several colors to identify voltage levels; or it could be a light-indicating board that indicates remote switch position via telemeter information and includes power or current flow data. Modern systems may have this data monitored via a supervisory control and data acquisition (SCADA) system. The power system information is then displayable on a computer monitor or wall-mounted display. A concern related to mimic bus, computer accessible, or other types of displayable single-line diagrams is maintaining the security and accuracy of the information presented. The desire to communicate information simply and easily must be weighed against the need to maintain reliable and secure information and means that allow both should be investigated.

4.2.4.2 Switching simulator

A switching simulator can be very useful for verifying the effects of any set of switching operations. Low-voltage toggle switches are substituted for circuit breakers and disconnect switches. Signal lamps indicate whether a circuit path has been omitted in the switching sequence, thereby offering the system operator a check on the switching plan prior to performing switching on the distribution system.

Interactive computer programs have been developed to provide the same system modeling as in the electrified-system single-line diagram. These programs can be rapidly manipulated to test any planned switching of an industrial plant's power system, but they have the added cost and effort of requiring absolute assurance that they are up to date with the real system. They can be used to check a proposed set of switching instructions and, in some cases, to print a set of instructions to be used in the field.

4.2.5 Panelboard directories

Panelboard directories are not single-line diagrams by definition, but they often fulfill the same purpose. Because they may be used in lieu of single-line diagrams, low-voltage lighting and panelboard directories should be maintained as well as all other electrical distribution system diagrams.

4.3 Plan (equipment location plan)

A site plan is usually a necessary accompaniment to the single-line diagram for a complete description and mapping of the industrial and commercial electric distribution system. The locations of the major components of the system are usually easy to visualize; however, circuit routing is difficult to comprehend without a site plan.

Site plans are important for a number of reasons, all of which could affect the operation of the industrial plant or commercial complex at some time. If a major catastrophe such as fire, flood, or storm damage should occur, a site plan would be an important tool for repair and reconstruction of the distribution system. The expansion and/or rearrangement of an electrical distribution system could be extremely difficult without accurate records of the location of existing system components. The site plan can be important for identifying the proximity of electrical system components to other maintenance work that may be taking place.

5. System operation and management

5.1 General

Regardless of size or complexity, a well-designed and constructed power system will not provide a safe and reliable operation unless it is properly managed. Although small straightforward power systems may be easily managed, as systems become larger in size and complexity, the problems associated with system operation and management increase, thereby requiring more time and attention from the system-operating personnel.

Good design, proper installation, quality assurance with acceptance testing, and sound operating and maintenance programs provide the basic foundation for the safe and reliable operation of industrial and commercial electric power systems. A plant engineer who is faced with the task of improving the plant's electric power system performance, however, will likely find that programs to reduce human error are often more cost-effective than system modifications or additional preventive maintenance. In fact, given good design and a sound maintenance program, the inherent system reliability can only be achieved by reducing operating error.

Therefore, it is important that proper operation and management of an electric power system also address potential human errors. Consider, for example, the following scenarios:

- Following a severe thunderstorm, a plant shift supervisor made a walk-through inspection of the plant's primary distribution switchgear. Upon seeing a red light for each circuit breaker, he or she immediately tripped each circuit breaker in order to obtain a green-light indication. Because he or she incorrectly thought that the red light meant "open," he or she shut down the entire plant.
- One of a plant's two steam boilers was down for annual inspection and maintenance. An electrician who was assigned to make a modification to the boiler control circuit erroneously began working on the operating boiler control circuit and shut down the operating boiler.
- An investigation of a 15 kV outdoor bus duct fault revealed that production personnel routinely turned off outside lighting at the beginning of the day shift by switching off circuit breakers in a 120 V distribution panel. The bus duct heater circuit was incorrectly identified and was being switched off with the lighting circuits.

It is a natural tendency to blame equipment for failures rather than human error. The bus duct fault described in the last example could have been classified as an equipment failure; however, the prime cause

was improper identification of a circuit breaker (a human error) that lead to erroneous switching off of the bus duct heaters.

Most plant electrical outages that clearly are not due to equipment failure, e.g., utility disturbances or storm related events such as lightning, can be prevented by making an objective investigation of the potential for outages and by following these guidelines:

- a) Document the system and identify the equipment.
- b) Plan switching operations in detail.
- c) Secure equipment from unintentional operation.
- d) Clearly define operating responsibility and adhere to it rigidly. System operation can and should be managed.
- e) Key interlocking of circuit breakers should be used where switching sequences have to be done in a specific order, or a system failure can be caused by closing a circuit breaker when the system is in the wrong configuration.

Effective managers of a power system will consider load distribution, system integrity, power factor, system protection coordination, and operating economics. Each of these areas is discussed in this clause, thus showing how all of these considerations relate to each other. No one area of industrial and commercial power system management is independent of the other.

5.2 Load distribution

How and where loads are connected to a distribution system is normally determined early in the system design. If the logic used in determining the load arrangement has been documented by the system designers, then the system operators should obtain and understand that logic. If it has not been documented, the logic should be developed and, if possible, the information for the development of that logic should be obtained from interviews with the system designers. If they are unavailable, that logic may be developed by studying the loads and classifying them by type. Loads should be classified by their criticality to the operation of the facility that is served by the electrical distribution system. For example, loads such as boiler fans or boiler feedwater pumps would normally be listed as more critical to an industrial operation than the load of a single production area because loss of the boiler area could trigger a chain reaction that would affect the entire industrial plant rather than just a single production area.

The importance of various loads should be kept foremost in the system operator's mind when planning or performing any switching of the system. Switching should be done in such a manner that the integrity of service to critical loads is maintained or, at least, the possible increased exposure to service interruption is minimized. Prior to the switching operation, the system operator should study the consequences of a service interruption and determine potential actions that may be taken should an interruption occur. Since the exact nature or cause of a service interruption cannot be determined beforehand, specific actions to take can also not be predetermined. However, general guidelines can be established to address the most likely scenarios and those of greatest consequence. One such action should be protecting the integrity of alternate sources. Certainly of critical importance is considering any switching actions or alternative power system arrangements that could potentially lead to a total power system collapse. Simple switching operations should not increase the likelihood of total system unavailability. Some computer programs can assist in determining the consequences of each switching action.

The system operator should always monitor the electrical system load distribution in terms of nominal electrical load measurement parameters such as watts, vars, and amperes to confirm that some circuits are not overloaded while other circuits are underutilized. Where parallel distinct circuits are available to carry the load, the system load should be balanced between the circuits, if the system connections make it possible. Critical service loads should be served from alternate circuits so that a single outage on one of the alternate circuits will not remove service from all critical loads. This concept may create a situation in

which the load magnitudes are not balanced. In this case, the operator should judge whether load balance or a reduced probability of the upset of critical facility operations is more important.

5.3 System integrity

5.3.1 General

Operation of electrical distribution systems should keep the whole system in service for as much of the time as possible. When a system has redundant circuits, as in the case of primary or secondary selective systems, the amount of time of operation as a radial system should be held to a minimum when an alternate circuit is removed from service for maintenance or other reasons. This is not intended to restrict maintenance or repair time but to verify that system integrity is maintained while a circuit is out of service. [See IEEE Std 141-1993 [B6] (*The Red Book*).]

A complex industrial plant may contain many redundant features that are related to the electrical power distribution systems. Redundancy allows for maintenance or repair on a portion of the system with minimum disruption to plant production. Conditions exist, however, that can easily undermine the reliability of redundant systems. Subclauses 5.3.2 through 5.3.5 discuss some of these conditions and ways in which to avoid them.

5.3.2 Considering outside forces

Operators need to consider all possible external and environmental influences that may compromise the integrity of the electrical distribution system and take the proper means to protect the system, to the greatest extent practical, from damage or interference that may be caused by those influences. The following abbreviated list outlines some possible factors to consider:

- a) Maintain good housekeeping at all times. Good housekeeping in the substations and around all apparatus is necessary if uninterrupted service is to be maintained.
- b) Strictly avoid using electrical rooms and spaces for manufacturing or storage, except for minor parts that are essential to the maintenance of the installed equipment.
- c) Provide good general maintenance consistently. This applies to area maintenance as well as to electrical maintenance. Such things as improper air filtration, a leaky roof, poor humidity control, or structural deficiencies may unintentionally have an adverse effect on the reliability of the electrical system.
- d) Carefully consider the possible need for operation of cranes in the area where outdoor bare conductors are used as a part of the distribution system. The unexpected movement of crane booms near energized power lines can affect system integrity as well as the safety of personnel in the area.

5.3.3 Equipment location

Ideally, distribution equipment should be isolated in a locked area, either indoors or outdoors, and should be accessible only to qualified personnel. Many reasons exist for this practice including safety of personnel, protection from accidental tripping caused by inadvertent contact, and protection of equipment from accidental or intentional damage. Numerous examples exist of electromechanical protective relays that are vulnerable to vibration accidentally being jarred and causing undesired relay operations. Broom handles seem to have an uncanny ability to find a control switch or bump the most sensitive relay. A breaker switching control handle appears to make an excellent coat hanger until the breaker is accidentally tripped and the lights go out.

Sometimes equipment cannot be located in an isolated area or the equipment has been located in an accessible area for many years. If such is the case, operators and plant managers should make sure equipment is properly marked and identified, and that personnel are trained to avoid the electrical equipment as much as possible. For example, if substations or distribution switching equipment are located near pedestrian or vehicular traffic ways, traffic paths should be clearly marked and identified to keep personnel and vehicles away from the electrical equipment.

5.3.4 Congested construction/maintenance activity

During maintenance shutdowns or during construction tie-in activity, the area around distribution equipment can become congested with materials and personnel. To protect the power system's integrity, the protection of nearby operating equipment from accidental operation should be addressed. For example, in redundant systems, such as primary selective or secondary selective distribution arrangements, a portion of the system may be energized while the equipment adjacent to it is serviced. In this situation, the two pieces of equipment should be individually barricaded, with personnel access strictly controlled during the periods of maintenance or construction. No exposure should exist that would allow personnel to accidentally bump against a control switch or protective relay.

5.3.5 Operating integrity

Inadequate system maintenance programs will also affect the operating integrity of the power system adversely. Failure to perform maintenance work on a system adversely affects its integrity. The system operator should evaluate the merits of a redundant system, with portions that are occasionally out of service for maintenance versus waiting for a total shutdown on a simple radial system. The best maintenance plan for the particular power system in question should be determined.

5.3.6 Grounding system integrity

Although a detailed discussion of grounding is beyond the scope of this document, grounding problems can sometimes cause issues with power system integrity and are therefore briefly mentioned in this subclause. A number of factors may cause grounding problems including, but not limited to, flawed ground system design, improper ground system construction, power system changes made without considering the effects on the existing grounding system, ground system failures or damage, or improper ground system maintenance. The system operator should be aware of potential ground system issues and be convinced that the system grounding has been adequately designed, constructed, and tested prior to starting up or taking over a power system. Grounding is covered in depth in IEEE Std 142™-2007 (*IEEE Green Book*) [B7] and its subsequent 3003 series dot standards as they become available.

Like other areas of the power system, the ground system needs periodic inspection, testing, and maintenance to retain its integrity. For further information on ground system testing and maintenance, the reader is referred to the IEEE Std 3007.2-2010.

Grounding system integrity is extremely important to proper power system integrity and, therefore, its operation. Consequently, addressing ground system flaws as soon as they become apparent and assuring that proper ground system inspection, testing, and maintenance occur at proper intervals are all critical to sustaining proper plant operation.

5.3.7 Design integrity

Design issues are outside the scope of this document, but because there are very few facilities that do not have some inherited design flaws that operators must typically deal with, the following design references are provided for further information: IEEE Std 142-2007 (*IEEE Green Book*) [B7] (referenced in the last

paragraph), IEEE Std 141-1993 (*IEEE Red Book*) [B6], IEEE Std 241™-1990 (*IEEE Gray Book*) [B8], and their subsequent dot standards as they become available.

5.4 Power factor

Low power factor will reduce system capacity and decrease efficiency. This capacity reduction occurs because the equipment, particularly transformers and wiring, is forced to carry larger reactive currents than would be necessary if the load's reactive power was provided by nearby capacitors. The results of a low power factor include increased heating of the equipment and conductors, as well as an increased voltage drop on the distribution circuits. Where voltage drops become excessive, the reduced voltage may cause some utilization equipment to operate less efficiently. This is especially true for motor-driven equipment where the motors can overheat if the voltage becomes too low. The effects of low power factor are manifest throughout the distribution system back to, and including, the source (e.g., a utility company tie or self-generation). Some utility tariffs include power-factor penalty clauses that add surcharges on the utility bill if a facility does not keep its power factor above a predetermined value. The following should be noted:

CAUTION

To system operators: Engineering support should be obtained when low power factor is to be addressed.

Many modern industrial and commercial power systems have equipment with non-linear loads such as adjustable speed drives. When non-linear loads are present, the harmonic distortion they create needs to be included in the analysis of power factor correction.

- a) System operators need to be aware of low power factor anywhere on the power system so that they can evaluate and correct the situation.
- b) Correction can take the form of adding power-factor correction capacitors either to motor circuits or as shunt banks for system sections or entire systems. Please see the caution to system operators above. If harmonics are not accounted for when adding power factor correction capacitors, harmonic resonant conditions may cause power system problems and equipment damage or malfunction. Engineering support should be obtained to determine the need and proper installation of power factor correction capacitors as well as the potential need for harmonic filtering or mitigation approaches.
- c) The operator should take advantage of any synchronous machines that may be on the system by using them to supply reactive flow into the system. Typically, synchronous generators are operated with a leading power factor to supply vars to the system. Synchronous motors usually are not loaded to their nameplate capability so these motors can generally be operated in an overexcited condition to supply vars to the power system.
- d) The use of high-power-factor lighting ballasts will avoid introduction of power-factor problems, and may improve the plant power factor significantly if lighting is a substantial part of the system load.

5.5 System protection coordination

5.5.1 General

Protective devices such as fuses and circuit breakers have ratings of how much fault current they are capable of interrupting. In order to ensure that all of the devices used for a particular application are within the proper rating, a short-circuit study is performed. The proper operation of the protective devices in the electrical distribution during an overload or short circuit consists of having the device closest upstream to the problem isolate it without any of the other protective devices opening. This is referred to as

“selectivity” or “coordination” of the protective devices. A coordination study is performed to determine the correct size and settings for all of the protective devices.

When an electrical distribution system is designed and constructed, a short-circuit and coordination study should be conducted, and circuit protective devices should be sized and set according to the results of the study. The system operators should obtain a copy of this study and verify that all of the protective devices have been set to the settings listed in the study. Whenever maintenance is performed on the electrical distribution system, these settings should be provided to the maintenance team and any discrepancies found during the maintenance should be documented and addressed.

In time, electrical system configurations often change due to the changing needs of the end users. When the system conditions change, the results that were obtained in the original short-circuit and coordination study may no longer apply to the current system. Therefore, to maintain good system management and operation, the coordination and capability of the electrical system should be reviewed periodically and always before any proposed changes are implemented.

WARNING

If the coordination and capability of the electrical equipment are not reviewed at the time of the changes, the changes could result in unnecessary tripping of a main breaker or, even worse, an explosion of equipment that was thought to be in good condition and properly utilized.

Unnecessary tripping, known as lack of selectivity, can be caused by poor coordination of circuit protective devices. When this occurs, the coordination study should be reevaluated.

WARNING

An equipment explosion can result from the interrupting capability of the circuit protective device being exceeded. Therefore, whenever power system changes occur that change the available short-circuit current to the system, e.g., a larger utility transformer is installed or an on-site generator is added, a short-circuit study should be performed.

5.5.2 Coordination of the power system for personnel protection

In the past, power system coordination was primarily concerned with system reliability and preventing installed equipment damage. While this is still important, the safety of the personnel working on the system is also a valid consideration. Coordinating power systems to reduce fault current and/or operating time can reduce the amount of arc energy that may be available, reducing the arc flash hazard. This would provide benefits in reducing personal protective equipment (PPE) levels, clearing faults earlier, and lessening damage that could occur to the system. However, system stability and reliability should be reverified to confirm that any changes do not impair proper operation. Additionally, instances may exist where the arc energy cannot be appreciably reduced. In recent years circuit breaker manufacturers have made information on instantaneous selectivity available for their circuit breakers. This approach is similar to the fuse ratio charts produced by fuse manufacturers. In many cases, it may no longer be necessary to slow delays or desensitize pickup levels of upstream devices as much as previously practiced to achieve significant levels of selectivity. For existing and new installations, it is suggested that overcurrent protective device manufacturers be consulted on how to obtain optimized selectivity with a minimum of negative impact on protection.

Maintenance of circuit protective devices is critical to the reliability of these devices. Inadequate maintenance can result in unintentional time delays in the operation of the device(s) that can affect the coordination of a system. Any unintentional time delay can also result in the unintentional tripping of upstream devices, shutting down even greater portions of an electrical system. Longer clearing times can

also contribute to increased incident energy if an arc flash were to occur, possibly exposing personnel to increased hazards. Clause 4 of IEEE Std 3007.2-2010 and Chapter 5 of IEEE Std 493™-2007 [B10] address electrical preventive maintenance and should be consulted with regard to the possible consequences of inadequate maintenance of circuit protective devices.

5.5.3 Utility systems delivering higher fault currents

The demand for electricity, particularly in the industrial and commercial environment, has been steadily increasing. Consequently, utility systems have grown much larger and have become capable of delivering much higher fault-currents at service points than in the past. Therefore, protective devices that were properly applied at the time they were installed may have become inadequate after the utility system changes, and the protective system may no longer be coordinated. When available short-circuit current increases to the point at which it exceeds protective device interrupting and withstand ratings, violent failure is possible, regardless of how well the devices are maintained. Accordingly, any changes to the power system that affect the available short-circuit current should be analyzed by a power system engineer to determine if equipment upgrades or replacements are also required.

5.5.4 Protection in an electrical distribution system

System and equipment protective devices are a form of insurance. This insurance pays nothing as long as there is no fault or other emergency. When a fault occurs, however, properly applied protective devices reduce the extent and duration of the interruption, thereby reducing the exposure to personal injury and property damage. If, however, the protective system does not match system needs properly, it is similar to an insurance policy that does not keep up with inflation; neither will provide adequate protection when needed. It is the responsibility of the system operator to verify proper system protection and coordination.

5.5.5 Protective equipment set to sense and remove short circuits

In medium-voltage systems, the protective equipment for feeder conductors is often set to sense and remove short circuits but not necessarily to provide overload protection of circuits. However, device settings are sometimes purposely chosen low enough to sense and provide some degree of overload protection. Operators should be aware of this so that a protective device that is set lower than what is necessary for coordination does not cause a false tripping action during system switching procedures. System protection coordination is an especially important consideration in switching systems with loop feeds and alternate sources. To avoid false tripping action, operators should be aware of the settings and any probable temporary overloads or circulating currents that may occur during switching.

5.6 Operating economics

5.6.1 General

It is important to operate an electrical distribution system economically because of the high costs of losses and the ever-higher costs of system expansion. Today, there are numerous methods for monitoring and controlling the power flow through the distribution system. These methods range from simple ammeter, voltmeter, wattmeter, and varmeter systems to complex SCADA systems. A system can be designed to fit the needs and budget of any sized facility.

5.6.2 Energy conservation

Energy conservation begins with thorough and complete design practices, and it is the key to the economic operation of a power system, regardless of the methods that are used to monitor and control the energy flow through the system. The system should be operated in such a manner as to keep losses to a minimum and to minimize any utility power factor or demand charges.

5.6.3 Power-factor correction

Power-factor correction, by the addition of capacitors at the facility service point, reduces power-factor charges from the serving utility. This, however, does not release any capacity of the load-side distribution system. Power-factor correction that is closer to the loads not only reduces power-factor at the facility service point but also reduces currents in the main feeder conductors. This reduces the system losses, reduces power-factor billing charges, releases circuit capacity, and improves voltage regulation. Furthermore, the subsequent release of circuit capacity allows additional circuit loading and therefore may be used to avoid costly system expansion projects.

CAUTION

To system operators: Engineering support should be obtained when low power factor is to be addressed.

Many modern industrial and commercial power systems have equipment with non-linear loads such as adjustable speed drives. When non-linear loads are present, the harmonic distortion they create needs to be included in the analysis of power factor correction.

5.6.4 Utility demand charge

Most utilities have a demand charge that is based on kilowatts, and an energy charge that is based on kilowatt-hours. In addition, some utilities include kilovolt-amperes in the demand charge and kilovolt-ampere-hours as part of the energy charge. The inclusion of the reactive as well as the real component of power use automatically includes power factor, and the utilities will generally charge a financial penalty for loads that operate below a specified minimum power factor. The power system demand level is dependent upon the type of industrial plant or commercial facility and how it is operated; this determines the plant or facility's load profile and, hence, its demand. The system operator, in conjunction with plant operation personnel, should develop the logic for the plant or facility's operation so that effective demand control can be practiced. Demand charges normally are maintained at peak levels for finite time periods after a new peak is established. For example, the cost of a single peaking event could have a recurring cost for as long as 12 months. Therefore, the lack of some form of demand control can escalate one apparently small indiscretion into a very expensive event. The unnecessary operation of spare equipment that adds load to the system, even for a short time, should be avoided so as not to increase demand peaks. The operator should be aware of the serving utility rate/demand structure in order to operate at peak effectiveness and to avoid any unnecessary demand charges.

6. System control responsibilities and switching and clearing procedures

6.1 General

System control and the corresponding switching and clearing procedures are a significant aspect of power system operation and management. However, it is not just the system operator and/or manager that are responsible for system control; everyone who interacts with the power supply and distribution system of an industrial or commercial facility has some responsibility for the control of that system. The owner has the

primary and ultimate responsibility for all operating occurrences on the power distribution system. In addition, those individuals who perform maintenance on the system, any contractors or others who may work on the system, as well as the utility, also have control responsibilities.

The complexity of control, and the level of technical and management attention required, increases with the complexity of the system. A simple, single-source radial supply system with one distribution panelboard or switchboard usually only requires minimal switching or clearing procedures (i.e., deenergizing a portion of the system and/or shifting load) for making the system ready for work. However, a system with loop feeds and alternate sources requires carefully studied and detailed procedures as an aid to maintaining personnel safety and providing operational integrity. Regardless of complexity, all power systems require certain responsibilities from those who operate, manage, or work on them. Those responsibilities and the switching and clearing procedures involved are the topic of this clause.

6.2 Responsibility of the owner

The owner has the ultimate responsibility for system control. This includes the responsibility of making certain that all other parties perform their work safely and at a level that is consistent with their responsibilities. In effect, the owner becomes responsible, to some degree, for the actions of all parties that perform work on or with the power distribution system in the facility.

The owner, or the owner's representative(s), should be aware and knowledgeable of all work that is performed on the system. This does not mean that the owner has to possess the technical knowledge of any and all details of the work to be performed, but it does mean that the owner should have a general understanding of what work is to be done on the system. The owner needs to provide for the deenergization of the system, isolation, lockout and/or tagout, and testing that are required before personnel are allowed to work on any portion of the system.

If the system is large and complex, the owner or the owner's representative(s) normally should utilize their standard clearing procedures to get the system ready. This usually includes providing all switching that is required to deenergize the system or the portion of the system in the work area, installing the necessary tags and locks to properly lockout/tagout all the pertinent isolating devices, and applying the proper personal protective grounding devices. On a simple radial feeder system, personnel, other than the owner or owner's representative(s), may be permitted to open the isolating device, lockout/tagout the isolating device themselves and apply personal protective grounding devices when necessary. The owner is still responsible to see that it is done properly.

Another responsibility of the owner is to control access to the power distribution system and equipment. In the United States, the owner is legally responsible for protecting the general population from possible harm that could result from proximity to or contact with the power distribution system. One of the best ways the owner can do this is by making portions or components of the power distribution system accessible only to qualified persons. Additionally, the owner should post proper warning signs and put proper security measures in place to prevent improper access to power system equipment and components.

OSHA has made it clear that owners, contractors, and any other individuals performing work on electrical power and distribution systems are required to discuss any safety hazards that may be present and any PPE that may be required, as well as any procedures and policies that may be used by any of their personnel during the work. NFPA 70E-2009 [B14] has also incorporated this multi-employer work-site requirement in Chapter 1, Article 110.5, and requires documentation of the meeting. The purpose of this meeting is to verify that all personnel working on the site have been adequately informed and made aware of the hazards, procedures, and requirements for the work involved.

6.3 Maintenance role

The importance of maintenance personnel taking the necessary steps to confirm that the system or the portion of the system on which they plan to work is in an electrically safe working condition cannot be overstated. Once in an electrically safe work condition, any additional protective devices, such as locks and tags, and personal protective grounding should be added where applicable. Before maintenance personnel start any work on the power distribution system, they are responsible for assuring themselves that the system is safe for work. Maintenance personnel should maintain the system isolation devices and lockout mechanisms in good working order. For a more complete discussion concerning safe practices and lockout/tagout requirements, see 4.5.2 of IEEE P3007.3/D1 (September 2010) (or 10.4.2 of IEEE Std 902-1998).

6.4 Utility responsibilities

When work needs to be performed on or ahead of the service entrance equipment, it is the responsibility of the serving utility company to isolate the utility power supply prior to the service point to any facility. The utility should supply, to the facility owner or the owner's representative(s), a point at which to padlock the service disconnect or provide some other means of service isolation control.

The serving utility has the primary responsibility to protect the service from possible disturbances or damage from outside influences. Utility service equipment also needs to be protected from access by unauthorized personnel.

6.5 Other workers

Outside contractors (i.e., non-owner personnel) should have a thorough understanding of the system on which they are going to work and how it is isolated from all energy sources. They should also understand how isolation and protection are achieved, and should comply with the owner's clearance procedures so that they can place and keep the system in an electrically safe work condition while they complete their work. For his or her own personal protection, each contractor employee should add his or her own personal lockout/tagout device(s) to the appropriate isolation point(s). When jobs require more workers than padlock positions exist, other methods such as the use of a lockbox that contains a lockout key should be considered. Multiple employees can place their locks on the lockbox thereby preventing access to the lockout key. However, any method used must comply with all safety regulations, e.g., in the United States, OSHA's lockout/tagout requirements. Relevant drawings and other information should be made available and should be reviewed with persons working on the system. (See Clause 3 for a more complete discussion of drawings.)

6.6 Switching procedures

Switching procedures are a routine part of operating any power system; however, regardless of how routine a switching operation has become or how often it is performed, every switching operation should be approached with the purpose of safely redirecting electrical power or isolating the power system. Electrical power systems control large amounts of energy, and switching operations require a lot of thought, preparation, and safety precaution for the level of hazard involved.

For those reasons, all switching should only be performed with written orders by qualified personnel. Switching devices that are not capable of interrupting the current while the equipment is operating should be specifically marked, and its limitations should be adhered to in switching orders. All switching orders should be thoroughly reviewed and approved by all personnel that will be involved in the operation. For further information on switching procedures, the reader is directed to 4.6.4, 5.7, and 6.4 of IEEE

P3007.3/D1 (September 2010) [information originally included in 10.5.4, 11.6, and 12.4 of IEEE Std 902-1998 (*IEEE Yellow Book*)].

The following text is an example of a switching procedure that a facilities or plant engineer might create to single-end a double-ended indoor substation or set of switchgear. The result of the switching procedure is that the gear, which was originally fed through both main circuit breakers with the tie breaker open, is upon completion fed through main circuit breaker #1 with the tie breaker closed. This example does not include lockout/tagout steps. Should a switching procedure require lockout/tagout, those steps should be called out in the procedure. Ultimately, it is the owner's responsibility to indicate and enforce proper lockout/tagout procedures. Application of locks and tags is, of course, dependent on the operation being performed and whether or not personal safety is a factor once the equipment is set to its desired state (i.e. deenergized). Although this simple example does not include details related to critical steps or what to do in the event that a step fails to produce the intended result, these and other details could be included in a detailed switching procedure as an aid to those performing the work.

Master Control Cabinet

1. _____ **LOCATE** Master Selector Switch.
2. _____ **SET** Master Selector Switch to **MANUAL**.
3. _____ **VERIFY** "SWBD NOT IN AUTO" Indicator Light is **FLASHING RED**.
4. _____ **SILENCE** Audible Alarm.

Tie Cubicle

5. _____ **LOCATE TIE** Circuit Breaker Control Switch.
6. _____ **SET** Control Switch to **CLOSE**.
7. _____ **VERIFY TIE** Circuit Breaker is **CLOSED**.
8. _____ **VERIFY RED** Status Indicator Light is **ON**.

Main Circuit Breaker Cubicle

9. _____ **LOCATE MAIN** Circuit Breaker #2 Control Switch.
10. _____ **SET** Control Switch to **TRIP**.
11. _____ **VERIFY MAIN** Circuit Breaker #2 is **OPEN**.
12. _____ **VERIFY GREEN** Status Indicator Light is **ON**.

A switching procedure should be created by the facility or plant engineer and walked down at least one time prior to execution of the procedure to verify that the procedure is correct and to verify that everyone that will be involved is familiar with and, most importantly, fully understands the procedure. Typically, the engineer will assign an operator to call out the steps in the procedure, and another operator(s) to actually switch or operate the equipment. Each step should be checked off and time stamped to allow for tracking purposes and the date of the operation should be recorded on the procedure. It is also helpful to include a one-line diagram of the system under operation to make it easier for the operators to understand the work being performed. Always indicate what safety PPE is required to be applied by the operators. If safety grounds or ground and test devices are required, the procedure should indicate how and where to apply the equipment. When safety grounds are used, the procedure to reenergize the system should include a step or steps specifically indicating when and how to remove them.

Another type of switching operation where caution is important occurs after an overcurrent protective device operates. At some point, the system must be reenergized. However, operations and maintenance personnel first need to determine the reason the overcurrent device operated. Any equipment faults require clearing and isolation prior to reenergizing the system or the power system could close back into a fault, which could be dangerous and/or cause additional equipment damage. Therefore, procedures to determine what occurred and how to reenergize the system should be thoroughly investigated and well thought out prior to any attempt at reenergizing.

6.7 Clearing procedures

Clearing procedures are a form of switching procedure with the purpose of isolating the circuit from the power system, typically as necessary for construction or maintenance purposes. Like switching procedures, the complexity of the power system normally determines the level of detailed planning that is required for system clearing procedures. A simple, single-source, radial supply system may only require opening a single switch or circuit breaker for circuit isolation. On the opposite end of the spectrum, a complex power distribution system may require numerous switching steps and have a very elaborate clearing procedure just to isolate a portion of the power system. The clearing procedures for both, however, should include checks to confirm that no other sources exist and that all of the correct isolating devices are being operated. It is important that all persons who may be exposed to a hazard, as a result of a switching action, be notified prior to the action.

For complex power distribution systems that require several switching steps to isolate a portion of the system, more elaborate clearing procedures are necessary and should be well documented. Written switching instructions are absolutely essential for systems that may have several sources into an area. When written instructions are used, a third party, who is familiar with the power system, should review them for errors and omissions. The consequences of learning about switching errors while in the act of switching are usually costly, especially when the wrong portion of the system is accidentally de-energized. The importance of sharing written procedures with all persons who are involved in the switching process cannot be overstated.

An up-to-date single-line diagram should always accompany the written switching instructions so that the switch operator can keep track of the progress through the system. A real-time, single-line mimic bus on a very complex system allows for the independent monitoring of the switching process through the system as component status is changed. Some mimic-bus systems allow the operator to simulate switching of the system off-line, which allows for the detection of possible errors before the actual switching is performed.

The clearing procedures should be completely written, checked, and understood by all persons involved before they are applied to any portion of the power distribution system. The instructions and/or procedures should include a verification that the power has been removed (by live-line testing or other means) followed by the lockout/tagout of isolating devices and the placement (and subsequent removal) of personal protective grounding devices.

Annex A

(informative)

Bibliography

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- [B5] *IEEE Standards Dictionary: Glossary of Terms & Definitions*.¹⁰
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⁷ The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

⁸ ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁹ CFR publications are available from the U.S. Government Printing Office, 732 N. Capitol Street, Washington, DC 20401, USA (<http://www.gpo.gov/>).

¹⁰ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

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¹² NFPA publications are available from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA (<http://www.nfpa.org/>). Copies are also available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).